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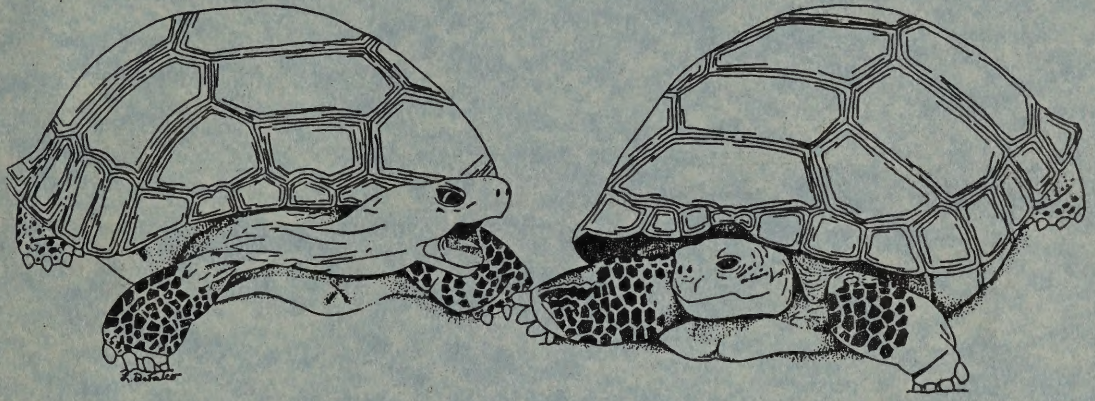
Nutrition and Foraging Ecology of the Desert Tortoise:

FY 1990 Annual Report



By

Todd C. Esque, Lesley A. DeFalco and R. Bruce Bury

Prepared for:

USDI Bureau of Land Management

Cedar City District, Utah

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1991

Prepared for:

USDI Bureau of Land Management

Cedar City District, Utah

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1.0 INTRODUCTION

We studied the foraging ecology of the desert tortoise (*Gopherus agassizii*) at two permanent study sites each 2.6 km^2 in 1990: City Creek, Utah (Coffeen *et al.* 1989, Esque *et al.* 1990) and Littlefield, Arizona (Hohman and Ohmart 1980, Duck and Schipper 1989). This was the second season of field work at City Creek site, and it was the first season that results were reported from Littlefield for this research project.

The City Creek and Littlefield sites are near the northeastern limit of the range of the Mojave Desert biome (Rowlands, *et al.* 1982). Precipitation patterns in the Mojave desert are highly variable, but most of this desert has winter rains. Annual vegetation is responsible for the spring 'desert bloom', which is dependent upon winter rains from October to May (Tevis 1958). In contrast to the central and western Mojave desert, the northeast Mojave desert has a bimodal rainfall pattern due to the effect of added moisture from occasional summer storms originating in the tropics.

The City Creek study plot (CC plot) is 4 kilometers north of the town of St. George, Utah. A survey of the City Creek plot in 1988 (Coffeen *et al.* 1989) revealed a dense population of tortoises (~230 tortoises/ 2.6 km^2) and the population had tortoises of all size classes.

The Littlefield study plot (LF plot) is 3.5 km north of the community of Littlefield, Arizona. This site supports a low density population of tortoises (~50 tortoises/ 2.6 km^2). It differs from the City Creek site in many ways (e.g. population density, soil substrate, vegetative composition, biomass production). Yet, the two sites offer a unique opportunity to observe tortoise adaptation in two habitats where fluctuations in major environmental parameters occur.

1.1 Vegetation in Relation to Climate and Soils

Vegetation provides both food and cover for the desert tortoise. We need to study vegetation in response to climate and soils to provide important insights on the ecology of the herbivorous desert tortoise. Productivity and distribution of annual and perennial plant species change in relation to fluctuations in precipitation, temperature and soil factors (Beatley 1974). These fluctuations affect the availability of food resources; and therefore, the energy and

nutritional requirements of the desert tortoise. Also, optimal vegetative conditions are influenced by climate and soils. Perennial vegetation provides shade and moisture to annual species, and both types of vegetation provide a valuable food resource to the tortoise. Annual production can be greater within the dripline of some perennials than within the intershrub spaces (Rowlands 1986). Most of the coarse litter in deserts is generated by perennial shrubs which adds to the soil. Shrubs also trap and consolidate blowing litter from cured annuals creating a microclimate favored by certain species. Besides providing a food source, perennial vegetation can provide tortoises with cover from thermal extremes.

Soils may be important factors directly or indirectly influencing tortoise distributions. Tortoises are known to ingest soils, presumably to supplement mineral nutrients in their diets (Sokol 1971, Marlow and Tollestrup 1982, Turner and Berry 1984, Esque *et al. this report*). Cryptogamic soil communities, which can be found at both sites, are comprised of fungi and mosses, and form highly organic crustal mats which affect soil moisture and nutrient availability in desert soils (Anderson and Rushforth 1976). The friability of soils (Wilson and Stager *in prep*) and locations of hardpan soils (Esque 1986) have both been suggested as limiting factors to desert tortoise distributions. Loose desert soils stabilized by extensive root systems may aid in the support of tortoise burrows. Clearly a better understanding of soil compositions is needed to determine the variation in forage quality in desert ecosystems.

1.2 Feeding Behavior

Desert tortoise feeding behavior is of paramount importance because debate exists over the possibility that habitat disturbances have reduced tortoise food resources. Livestock have been implicated in this debate because of the effects of grazing on available plant biomass and because of resultant changes in floral composition of desert habitats from secondary disturbances (i.e., soil disturbances and introduction of non-native annual plants). However, empirical data on desert tortoise foraging behavior in relation to livestock grazing are limited.

An understanding of tortoise feeding behavior depends on knowledge of diet selection. Do tortoises forage by selecting their diets from among an array of

species, or do they feed on species which they encounter randomly? The question must be designed to test hypotheses on the diet of desert tortoises, thus eliminating or corroborating one potential limitation to tortoise populations. Selection behavior describes how a tortoise feeds on a species or part of a plant with greater frequency than the plant species occurs in the habitat. Through a complete analysis of selection by means of direct tortoise observations and fecal analysis, fundamental questions such as "what species of plants do tortoises eat" and "what investment is made toward acquiring various species under different environmental conditions" may be better understood.

Tortoises eat bones, rocks, soils and fecal pellets. We have considered these striking behaviors in light of acquiring supplemental nutrients. Consumption of bones is known as osteophagy, of rocks as lithophagy, of soils as geophagy, and fecal pellets as coprophagy. Several vertebrate species supplement dietary requirements of minerals by feeding on bones, rocks, fecal pellets and soils (Anderson 1974, Brothwell 1976, Krausman and Bissonette 1977, Robbins 1983, Barrette 1985, Denton *et al.* 1986, and Duthie and Skinner 1986). We observed tortoises eating bones at City Creek and the Woodbury-Hardy, Utah site in 1989 (Esque *et al.* 1990). In this report we describe further field observations of osteophagy. These observations are being prepared for publication (Esque and Peters *in prep.* and Peters and Esque *in prep*).

1.3 Home Range

The study of home range is important to the understanding of the desert tortoise for many reasons. The size of home ranges of individuals may be an indicator of the status of a particular population (Stickel, 1950); i.e., environmental factors, physiology, population size and territoriality are variables that may influence home range. Seasonal or annual fluctuations in home range may indicate changes in the needs of the desert tortoise.

1.4 Plant nutrition

Plant nutrition must be considered when addressing the foraging ecology of the desert tortoise. Once the pattern by which tortoises acquire their food has been described, the nutritive value of the food they eat must be determined. Not only is this information important when considering the health of tortoise populations,

but it aids in predicting how populations will fare as introduced plant species become more prevalent and as more valuable habitat is altered.

1.5 Alternative Methods of Sampling Stomach Contents: Fiber-optics

Traditionally, animals have been sacrificed to extract the stomach for analysis. With the federal listing of the desert tortoise to threatened status, this method becomes inappropriate. Therefore, in addition to tortoise observations and fecal analysis, we explored other methods through which the stomach contents of the tortoise could be sampled safely and efficiently.

2.0 STUDY SITE DESCRIPTIONS

2.1 City Creek Study Plot

City Creek is at an elevation of 975-1067 m (3200-3500 ft.). This site is diverse due to the highly variable slope and exposure. This plot has been stratified into four habitat types (Esque *et al.* 1990): Dune, Transition, Rocky Transition and Rocky habitats. Stratifications were based on vegetation and edaphic characters (*i.e.*, dominant perennial species, particle size and composition of soils). Some soils had a surface mat of lichen and mosses known as a cryptogamic community (Anderson and Rushforth 1976). Cryptogams may affect soil moisture and nutrients. Dune habitat was dominated by an *Artemesia filifolia-Ephedra nevadensis* perennial association with non-cryptogamic, wind-blown hummocks of fine sand and less than eight percent clay. Transition habitat was dominated by *Gutierrezia* ssp. and soils usually supported a well-established cryptogamic community. Rocky Transition habitat had a vegetation association dominated by *Coleogyne ramosissima* with outliers from Rocky and Transition habitats and poorly developed rocky soils. Rocky habitat had little or no soils and was dominated by expansive slabs of Navajo sandstone.

2.2 Littlefield Study Plot

Littlefield is located 3.5 km north of the community of Littlefield, Arizona. The escarpment of the nearby Virgin and Beaver Dam Mountains causes an orographic uplift with additional rainfall on a local scale at the Littlefield study site (John Payne *pers. comm.*). The site is located on the lower bajada, draining on a gentle slope to the south into the Virgin River less than one km away. Topography generally consists of flat benches separated by shallow washes or deeply cut arroyos (up to 6 meters deep). Soils are comprised of

alluvial deposits. The Littlefield plot is characterized as Mojave desertscrub (Brown 1982). *Larrea tridentata* and *Ambrosia dumosa* are the woody perennials that contribute most to the physiognomy in the immediate area, while *Ceratoides lanata* and *Lycium spp.* may be locally important. Cacti such as *Ferocactus acanthodes*, *Neolloydia sp.* and *Opuntia basilaris* are locally abundant as are perennial grasses such as *Hilaria rigida* and *Erioneuron pulchellum.* The composition of perennial vegetation in the area may have changed since the introduction of livestock (Hohman and Ohmart 1980) . But, such claims cannot be substantiated empirically since quantitative records of vegetational change are lacking in that area. Annual vegetation composition has changed with the introduction of *Erodium cicutarium, Schismus barbatus, Bromus tectorum, and Bromus rubens*; exotic grasses associated with the introduction of livestock. *Bromus rubens* and *B. tectorum* have increased in density in other parts of the Mojave desert (Hunter and Medica 1989). Where an abundance of introduced species existed (*B. rubens, B. tectorum, Erodium cicutarium, Sisymbrium altissimum,* and *Schismus* sp), there was a poor display of native desert wildflowers (Hunter and Medica 1989).

Hohman and Ohmart (1980) described two habitat types at LIttlefield; flats and washes. We further stratified the Flats habitat type into three sub-habitat types based on vegetative and soil characteristics: *Larrea tridentata-Ambrosia dumosa* habitat, *Larrea tridentata-Ambrosia dumosa-Ceratoides lanata* habitat , and *Larrea tridentata-Ambrosia dumosa-Hilaria rigida* habitat (referred to as LA, LAC, and LAH, respectively). Wash habitat constitutes the deep cuts in the homogeneous flats with largely calcareous soils. *Larrea tridentata* and *Ambrosia dumosa* were woody perennial plants that contributed most to the physiognomy in the immediate area.

3.0 METHODS AND MATERIALS

3.1 Weather and Climate

Climate data are based on permanent weather stations in Beaver Dam, Arizona and St. George, Utah (NOAA 1957-1990 and NOAA 1928-1990). We used data on average monthly ambient temperatures, average monthly precipitation and average monthly mean maximum and minimum soil temperatures (available only for St. George, Utah). Total monthly precipitation was compared to the mean monthly precipitation of each station throughout the history of their

establishment. Timing and quantity of rainfall were compared to an earlier model used to predict annual vegetative biomass production at the Nevada Test Site (Beatley 1974).

3.2 Vegetation

We sampled annual and perennial vegetation at City Creek in 1989 and 1990 and at Littlefield in 1990. All sampling methods were identical between sites. Plant lists were compiled during quantification of vegetation and during daily visits to both sites. All species were identified using Welsh *et al.* (1987), Jaeger (1979), and through comparison with BLM - Arizona Strip herbarium specimens. We used data from Hohman and Ohmart (1980) to compare vegetation with our results for the Littlefield site.

3.2.1 Perennial Vegetation

We employed the line-intercept method (Canfield 1941) in 1990 to replace the belt transect method used in 1989 at City Creek (Esque *et al.* 1990) because the line-intercept method increased the number of samples (transects) while decreasing the amount of labor for each transect compared to belt transects.

The line-intercept method eliminates overestimation of vegetative cover, but it does not yield density nor frequency information. Additional belt transects could be completed if further perennial quantification is needed. Density and frequency were measured at City Creek in 1989 with belt transects while cover was measured in 1990 using the line-intercept method.

Line-intercepts were conducted in the early spring before tortoises became active so that observations on tortoise activity were not lost. Belt transects sampled in 1989 at City Creek were re-sampled in 1990 using the line-intercept method. In every case, the line was extended along the eastern edge of each previously measured belt transect. Additional randomly-selected transects were established and marked with 0.6 m tall reinforcement bar. One piece of bar was used to mark the ends of each 50 m transect. Transects were aligned in a north-south orientation (using grid north corrected with declination). Transects that had been established at Littlefield by Hohman and Ohmart (1980) were re-sampled. They did not require additional reinforcement bar as they were already marked by 2 m tall metal fence posts. All transects were

numbered with an aluminum tag to facilitate relocation and identification in the future.

Cover of perennial species was calculated by measuring the intercepting vegetative crown along the 50 m transect line. Estimates were calculated for minimum barren ground cover (ground void of perennial cover) by subtracting total perennial cover from 50 m. That resulted in a minimum vegetational cover estimate because some plant crowns were expected to overlap; however, observation showed that in the open desert habitats of the northeast Mojave desert, this effect was minimal. A community coefficient (Barbour *et al.* 1987) was used as an index of similarity between the study sites. The community coefficient (S) was calculated as:

$$S= \frac{2C}{A+B} \times 100\%$$

where 'C' was the number of species common to both habitat types, 'A' was the number of species found in the first habitat, and 'B' was the number of species found in the second habitat type. If S was equal to zero percent, there was no overlap between the habitat types; conversely, an S value of 100% indicated complete species overlap.

3.2.2 Annual Vegetation

We established annual quadrats at both City Creek and Littlefield in the same three weeks to ensure comparative data. Concurrent sampling reduced the chance of confounding data due to over-curing of the plants and resultant losses in biomass. Winter annual species were intensively sampled at City Creek from 3 May - 22 May 1990 and at Littlefield from 1 May - 14 May 1990. Summer flora of the each study site was not quantified.

We sampled the winter annual vegetation independent of the perennial transects in 1989. In 1990, we placed annual quadrats at regular intervals on perennial line-intercept transects. Five annual quadrats were spaced 10 m apart on each 50 m transect. As in 1989, we used one -m^2 quadrats since smaller quadrats did not provide adequate samples for the most common species. Beginning at the south end of each transect, annual plants were sampled using one -m^2 on the east side of the line-intercept transect . In the future, annuals can be sampled at offset intervals on the west side of transect

lines. Quadrats started at point zero on the 50 m tape and placed every 10 m thereafter. Adequacy of sampling in each habitat type was determined by graphing the cumulative variance versus the total mean biomass for all species on one-m^2 quadrats. In this way, we extrapolated the number of quadrats required to yield an adequate sample without oversampling. Cover was measured through a clear transparency marked with a 1cm^2 grid held directly over the quadrat. Density and percent frequency were calculated for each species. Finally, the samples of annuals were collected and separated from their roots, air-dried and then weighed to obtain the total aboveground dry biomass. Most measurements were converted from one square meter data to hectare. The similarity index used for perennials was also used for annual plant species.

3.3 Feeding Observations, Fecal Analysis, and Osteophagy

Feeding observations were made from 8 April - 27 June 1990 at City Creek and from 4 May - 22 June 1990 at Littlefield. Early in the field season, daily observations commenced early in the morning (0600-0800 h MST) and continued through the late afternoon. Later in the field season, as daytime temperatures elevated, tortoises were observed from early to mid-morning (ca:0530-1030h MST) and additional observations were conducted in the late afternoon (ca:1700-2030h MST) when tortoises reappeared during periods of less severe temperatures. We located tortoises using radio-telemetry before they emerged from their nighttime cover sites. Observers placed themselves a short distance away (5-20 m) and sought cover using natural blinds out of eyesight and earshot of the tortoise. As tortoises emerged, we noted the behavior of the tortoise using a tape recorder including: time and location tortoise emerged from cover site, type of cover site, distance travelled during observation, number of bites taken of each food item, food items ingested (including bone, fecal pellets, soil, and litter), interactions with other animals, time and location that tortoise entered another cover site and type of cover site used at the end of our observations. After each daily observation, we transcribed tape recordings onto data sheets. We entered data into a computer data base for later tabulation and statistical analysis.

Concurrent with tortoise observations, tortoise fecal pellets were collected for microhistological analysis. Identifications were made to the finest taxonomic

determination possible (species at best). Fecal pellets were collected at City Creek from 8 April - 25 June and at Littlefield from 23 April - 21 June. Only fresh pellets were collected. These fecal pellets were black, slightly moist, and they appeared to have no wear from age. Fecal pellets from both sites were stored in paper envelopes, labelled, and frozen for analysis at the Composition Analysis Laboratory, Range Science Department, Colorado State University. Fecal pellets were separated into three groups according to date: April, May and June fecal pellets. A subsample of fecal pellets was taken from the pooled fecal pellets to randomize sampling. Fecal pellets prepared for microhistological analysis by grinding the samples and mounting them on microscope slides (Hansen *et al.* 1976). Relative percent frequency was used for comparison with feeding observations, calculated as the percentages of a series of 20 standardized fields present on each slide pooled to yield the percentage frequency of each species on all slides combined.

In 1989, a wild tortoise was presented with the weathered bones of a range cow that had died on the City Creek site (Esque *et al.* 1990). That tortoise consumed a small portion of the bone with little hesitation. In 1990 a simple field trial was developed to investigate the behavior of tortoises presented with bones at the City Creek site. Eleven wild tortoises were presented with a sample of weathered cow bone that had been collected on the periphery of the study plot. We used a different piece of bone for each trial to reduce the possible enhancement or suppression of osteophagy by tortoise scent lingering on the bone from previous trials. However, since the bones were collected from tortoise habitat, it was not possible to control for scent which may have lingered from encounters prior to collection. The bone specimens used in the trials were weathered and flaking since tortoises were observed only using those bones which they could break in their beaks or swallow whole. Tortoises which were tested were not part of our feeding observation trials and therefore were not habituated to human contact. After presentation, the observer then stepped back about 3 meters and observed the behavior of each tortoise for 5 minutes. If the tortoise responded to the bone by sniffing and taking it into its mouth, then the trial was recorded as a positive response to osteophagy.

3.4 Home range

We attempted to locate 10 tortoises with radio transmitters at least once per week from early March through September. Home ranges for 1990 were calculated using the minimum convex polygon estimator replacing the non-circular plot method (Jennrich and Turner 1968) used in 1989. To calculate the minimum convex polygon, a program was written in True Basic (Tracy 1990) using tortoise localities transcribed to a binomial coordinate system. Home range size means means were compared using a student's t-test with a 95% confidence limit.

3.5 Feeding selectivity

Quantitative analyses between plant species eaten and plant species available were used to determine the extent to which tortoises selected food items. The 'observed' data in this chi-squared analysis represented the frequency with which tortoises fed on plant species per 1-m^2 quadrat and the 'expected' data represented the frequency with which plant species occurred on 1-m^2 vegetation quadrats. In the event that tortoises located plant species not represented in vegetation analyses, the expected values would normally result in zeroes. As a rule of thumb, values less than 5 are generally not recommended for use in count data.

Feeding observation data were used between 8 April - 27 June, 1990 at the City Creek site, and 4 May - 22 June at the Littlefield site. Data were based on direct observations of tortoise behavior totalling 267 hours at City Creek and 187 hours at Littlefield. Criteria for beginning and ending observations at both sites were identical, and observers were rotated between sites to yield equal effort and coverage. At City Creek, tortoises spent 23% of the observation time feeding, in contrast tortoises at Littlefield spent only 6.4% of observed time feeding. At City Creek, ten tortoises were monitored of which only eight were observed feeding. At Littlefield eight tortoises were observed feeding.

We used vegetation transect data to assessthe frequency of occurrence of plant species per square meter (4.2 Vegetation). At City Creek, vegetation data were stratified into habitat types, and selection was tested within each habitat type (2.0 Study Site Descriptions). Frequency of plant species fed on by tortoises was determined using feeding observations (4.3 Field Observations of Desert

Tortoises). Feeding bouts (a tally of feeding observations of tortoises during an entire activity period, i.e. one morning of activity) were separated into feeding patches (locations where tortoises stopped to feed). Feeding patches were one m^2 based on the assumption that under most conditions the tortoises could reasonably survey an area of one m^2 to search for food species if indeed they do 'search' for 'preferred' species.

3.6 Plant Nutrition

We collected plant species for nutritional analysis based on lists in the literature for 1989; however, additional plant samples were collected that were potentially important to tortoise nutrition based on field observation of tortoise foraging activity. These new species were used in 1990 but not in 1989, or they were more prevalent and warranted additional consideration in 1990. The nutritional samples were collected on three separate occasions during the season, and phenology of each species was noted at the time of collection.

3.7 Fiber-optics

Several methods for sampling stomach contents have been developed and used on turtles in the past. With freshwater turtles it was possible to turn the turtle upside down and flush out the contents by introducing water into the stomach (Legler 1977; Parmenter 1978). More recent methods incorporated the use of a gavage tube (tube inserted into the stomach) by either flushing the contents out of the stomach for collection or by withdrawing a sample with the gavage tube. We attempted to retrieve stomach contents with a gavage and syringe on 6 laboratory animals, but we were unable to acquire an adequate sample (Esque *et al.* 1990). Dead tortoises were dissected to explore the gut morphology of desert tortoises.

To explore other techniques, we consulted veterinarians and medical specialists to design a non-destructive method to sample the stomach contents of a desert tortoise using fiberoptic technology.

A flexible ureteroscope or a rigid cystoscope was used to gain visual access through the anterior gastrointestinal tract of tortoises. The term *endoscope* is used here to depict either type of instrument. A Surgitek SU-11 flexible ureteroscope with a length of 700 mm and a 4 mm diameter was used.

Cystoscopes had 30° and 70° visual angle microlenses, manufactured by American Cystoscope Makers, Incorporated. This model had a non-flexible, surgical steel sleeve (23 French) measuring 21cm long and 6 mm in diameter. The ureterscope and cystoscope were illuminated with a powerful xenon or incandescent light source, and a camera attachment was used when the procedure was viewed on video. Both light sources may be powered by a small gas generator at remote field locations.

Fiberoptic endoscopy was used on 6 captive tortoises in 1989 to develop techniques (Esque *et al.* 1990). An additional 3 captive tortoises were used at St. George just prior to working with wild individuals. We sampled 16 wild desert tortoises near St. George, Utah in early July, 1990. All animals were adults greater than or equal to 180 mm maximum carapace length (MCL). We sedated each tortoise during these trials with ketamine chloride, which is a safe and commonly used sedative for reptiles. We have used ketamine chloride on other occasions (during physical examination of health) with tortoises of varying size, weight, and sex; we experienced no mortalities with the drug. Dosages were 10 ml/kg of tortoise body mass during initial trials, but this dosage was not entirely effective (tortoises remained active). On a second trial, 11 to 15 ml/kg were used on captive tortoises and tortoises still retained a high level of mobility. Also, captured wild tortoises appeared to have a higher threshold for the anaesthetic. For wild animals, we used ≤22 mg/kg of anaesthetic. Under this dosage, tortoises were still conscious (e.g., eyes open) and did not require respirators, yet they were docile and easy to manipulate. Tortoises retained some mobility. But we elevated a tortoise on a short pedestal (slightly narrower than the diameter of the plastron) so their legs did not offer resistance. A coffee can filled with cement worked well for a pedestal. We attached nylon straps to the can to firmly secure the tortoise. We worked with a tortoise approximately 10-15 minutes after the drug had been administered.

After sedation, a plastic mouth piece was placed into the tortoise's mouth by gently pulling down at the junction of the upper and lower mandibles. The mouth piece was a modified syringe container with the closed end cut off and filed down to prevent any injury to the tortoise's mouth (~1 cm dia.). Using this narrow mouth piece, any jaw discomfort was minimized while offering a passageway through which to pass the fiber scope. At the same time the mouth

piece was positioned, a rubber catheter was installed into the stomach to allow any introduced air or water to pass the glottis and prevent aspiration. Each tortoise was monitored constantly to ensure that instruments did not block the glottis and impair respiration. The scope was lubricated with sterile surgical lubricant before introducing it into the mouth. Care was taken to pass over the trachea and into the esophagus while preventing air or water to escape through the scope portal. Once into the esophagus, viewing of the passageway was facilitated by the scope ocular. It was most effective to use only lubricant on the endoscope to access the stomach; however, if it was necessary to open up the passageway slightly (as sometimes the gastrointestinal linings may collapse onto the scope making viewing difficult), air or water was slowly introduced using the hand controls on the fiberscope core. This procedure sometimes resulted in excess air bubbles interfering with the view through the ocular. The rubber aspirator facilitated the expulsion of any water or air introduced during the procedure. A sample of gastric juices was acquired by gently moving the catheter in and out to pump out a small sample and pH was estimated using litmus paper.

On another occasion rigid endoscopes were lubricated with sterile surgical lubricant and guided into the relaxed tortoise's esophagus until it reached the stomach. We then passed a guide wire into the stomach via the endoscope portal. Also, retrieval tools such as a three-point grabber and a three-point basket were introduced into the tortoise's stomach through the cystoscope portal. With careful manipulation of the retrieval devices, we could extract portions of the food bolus residing in the stomach. Food samples were deposited into a vial containing 70 % isopropyl alcohol for preservation and future analysis.

After the procedure was completed, we removed the retrieval tools and aspirator, then the scope and finally the plastic bit from the tortoise's mouth. The tortoise was then placed in a cardboard box and observed until recovery. The boxes were stored in a shaded location away from drafts and temperatures were monitored. Tortoises were capable of some mobility within 30-60 minutes after the procedure, depending on the dose administered. However, each individual was monitored for a minimum of four hours. Release depended on environmental conditions 6-12 hours after the fiber optics procedures were

completed. Most tortoises were kept overnight. Tortoises retained over night were maintained at ambient temperatures.

Protocols for care and handling were followed to insure sanitary conditions from point of initial capture to final release. Radioed tortoises are monitored in the field on a continuing basis following procedures and will continue to be monitored in the 1991 field season. No mortalities have occurred during or after the procedures.

4.0 RESULTS

4.1 Weather and Climate

4.4.1 City Creek

Figure 1 summarizes the precipitation data for 1989 and 1990. City Creek received conceivably inadequate rainfall for the normal germination of winter annual seed stocks during the late September through early December rainfall period (Beatley 1974) yet a late winter rainfall period (48.51 mm: mid-December through mid-March) provided additional precipitation for scattered germination of some winter annuals.

For 1988 and 1989, total monthly precipitation from late September through early December has been less than the average for the winter months for the sixty-three year history of the St. George weather station.

4.4.2 Littlefield

Total winter precipitation in 1989 (late September through early December) at Littlefield was 26.42 mm. Based on the model proposed by Beatley (1974), this amount of rainfall would produce only scattered germination of winter annual seed stocks. Added precipitation in January through March (82.04 mm) may have been adequate to encourage additional germination but it more likely contributed to the vegetative growth of annuals that were already established.

Winter rainfall in the October through December months in the last three years has been below the mean monthly rainfall for the thirty-five year history of the Beaver Dam weather station (Figure 2).

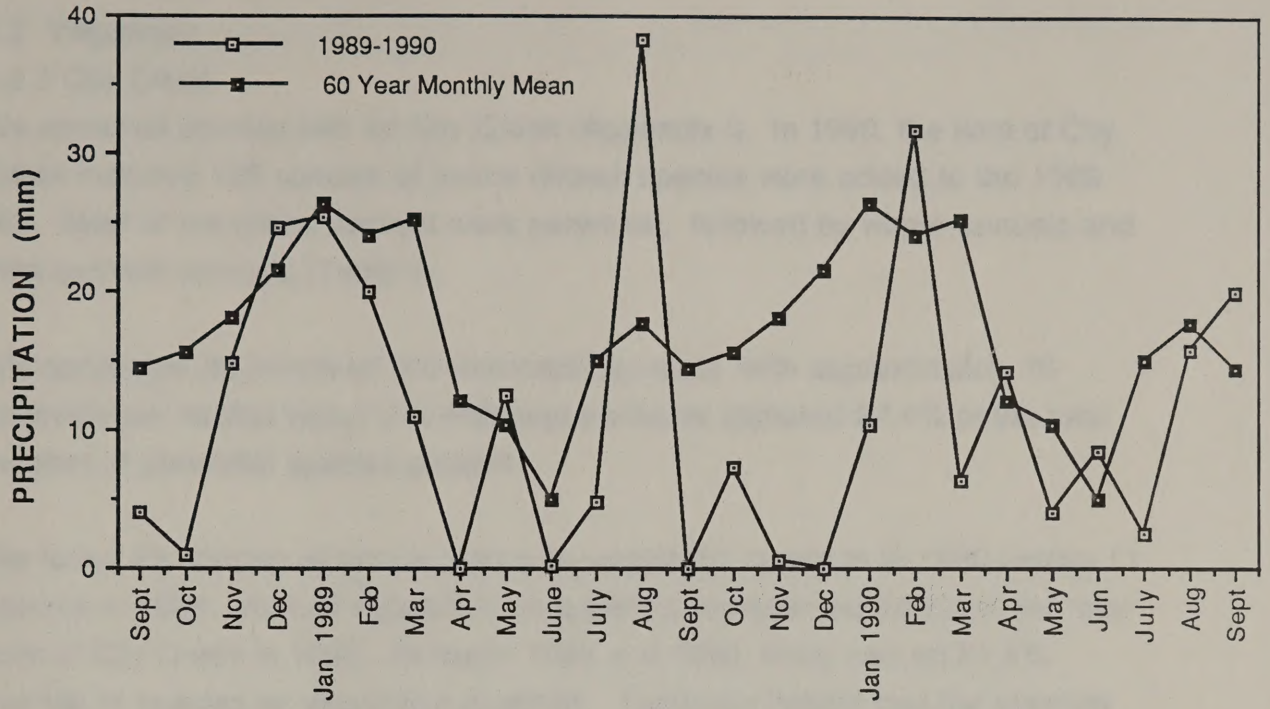

Fig. 1. Comparison of recent average monthly precipitation to recorded average monthly precipitation at St. George, Utah.

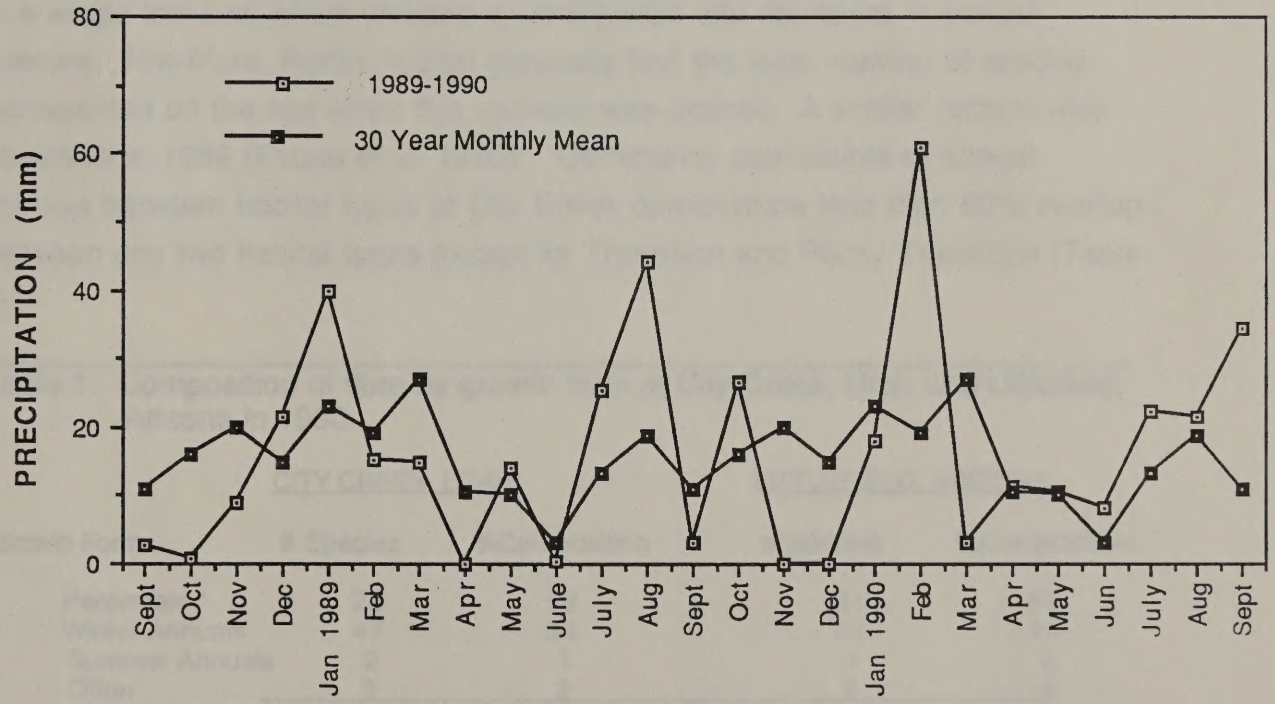

Fig. 2. Comparison of recent average monthly precipitation to total recorded average monthly precipitation at Beaver Dam, Arizona.

4.2 Vegetation

4.2.1 City Creek

We compiled species lists for City Creek (Appendix I). In 1990, the flora of City Creek included 125 species of plants (fifteen species were added to the 1989 list). Most of the plants present were perennial, followed by winter annuals and then summer annuals (Table 1).

We conducted 39 perennial line-intercept transects with approximately 10 transects per habitat type. Line-intercept transects captured 27.4% of the total number of perennial species present.

We found 28 species of annual plants on vegetation quadrats in 1990 versus 11 species in 1989. Annual vegetation on quadrats represented 55.3% of the total flora of City Creek in 1990. Between 1989 and 1990, there was an 81.8% overlap of species on vegetation quadrats. Transition habitat had the greatest number of species (N=17), and Rocky Transition habitat had the least number of species (N=8). However, a higher diversity of annuals in Rocky habitat was due to a single transect which crossed a xeroriparian site abundant in annual species. Therefore, Rocky habitat generally had the least number of species represented on the site when this transect was omitted. A similar pattern was observed in 1989 (Esque *et al.* 1990). Community coefficients of annual species between habitat types at City Creek demonstrate less than 50% overlap between any two habitat types except for Transition and Rocky Transition (Table 2).

Table 1: Composition of flora by growth form at City Creek, Utah and Littlefield, Arizona in 1990.

	CITY CREEK, UTAH		LITTLEFIELD, ARIZONA	
Growth Form	# Species	%Composition	# Species	%Composition
Perennials *	73	59	31	54
Winter Annuals	47	38	24	40
Summer Annuals	2	1	1	2
Other	3	2	2	4
Total Number	125	100	57	100

*Perennial vegetation includes woody, tuberous, and grass species.

Table 2: Community coefficients (%) of annual vegetation in each of four habitat types at City Creek Study Plot, St. George, Utah in 1990.

	Dune	**Transition**	**Rocky Transition**
Rocky	27	53	48
Rocky Transition	24	40	X
Transition	46	X	X

Biomass, cover and density of annuals was lower in 1990 than in 1989. Total mean biomass production of annual species was 8.79 kg/ha in 1989 versus 7.59 kg/ha in 1990 (Table 3). Cover and density of annuals were lowest in Dune habitat and highest in Transition habitat. *Bromus spp.*, *Erodium cicutarium* and *Schismus barbatus*, all introduced species, were the major contributing species for any descriptive parameter (Table 4).

Summer annual productivity was not quantified because only one visit was made to City Creek on 17 September, 1990. Ocular survey at that time indicated that there was considerable biomass available in sun cured plants but little species diversity. The two most abundant summer annual species present were *Bouteloua barbata* and *Pectis papposa*.

Table 3: Comparison of estimated available biomass (kg/ha) at City Creek for 1989 and 1990.

	HABITAT TYPE			
Year	**DUNE**	**TRANSITION**	**ROCKY TRANSITION**	**ROCKY**
1989	1.44 (N=40)	21.59 (N=40)	7.74 (N=40)	5.3 (N=38)
1990	0.57 (N=20)	16.16 (N=30)	4.74 (N=20)	4.6 (N=20)

Table 4: Descriptive statistics for annual vegetation among four habitat types at City Creek, Utah in 1990.

	Freq.	Mean Dens. (#/m^2)	Std. Dev.	Mean Cover (cm^2/m^2)	Std. Dev.	Mean Mass (g/m^2)	Std. Dev.
DUNE (N=20)							
Cryptantha micrantha	.30	0.700	1.342	2.700	6.284	0.009	0.023
Bromus rubens	.25	0.500	1.051	1.300	3.600	0.014	0.040
Eriophyllum wallacei	.15	0.200	0.523	0.350	0.875	0.006	0.016
Euphorbia parryi	.15	0.150	0.366	2.425	7.493	0.006	0.018
Phacelia ivesiana	.15	0.200	0.523	0.550	1.572	0.005	0.015
Schismus barbatus	.10	0.150	0.489	0.175	0.591	0.001	0.004
Eriastrum eremicum	.05	0.150	0.671	0.950	4.249	0.003	0.012
Lotus rigidus	.05	0.100	0.447	3.050	13.640	0.007	0.033
Stephanomeria exigua	.05	0.050	0.224	1.400	6.261	0.004	0.020
TRANSITION (N=30)							
Schismus barbatus	.80	10.733	15.118	23.417	38.460	0.294	0.644
Bromus rubens	.73	13.400	20.589	18.583	26.498	0.696	0.959
Eriophyllum wallacei	.73	4.600	5.157	5.950	7.888	0.092	0.115
Erodium cicutarium	.43	3.867	6.553	14.233	22.540	0.445	0.848
Cryptantha micrantha	.33	0.500	0.820	1.917	3.952	0.008	0.014
Bromus tectorum	.20	0.167	0.461	0.800	2.310	0.014	0.040
Eriastrum eremicum	.17	0.267	0.640	0.850	2.536	0.005	0.015
Gilia sp.	.13	0.300	0.877	0.667	2.078	0.011	0.033
Cryptantha nevadensis	.13	0.133	0.346	0.467	1.479	0.008	0.027
Chorizanthe thurberi	.10	0.403	1.300	6.753	0.007	0.007	0.035
Phacelia ivesiana	.10	0.100	0.305	0.367	1.377	0.008	0.031
Descurainia pinnata	.07	0.200	0.925	0.600	2.415	0.009	0.037
Plantago patagonica	.07	0.133	0.571	0.300	1.317	0.005	0.019
Eriogonum thomasi	.03	0.067	0.365	0.333	1.826	0.004	0.024
Eriogonum maculatum	.03	0.033	0.183	1.000	5.477	0.004	0.023
Gilia leptomeria	.03	0.033	0.183	0.233	1.278	0.004	0.021
Cryptantha sp.	.03	0.033	0.183	0.067	0.365	0.001	0.008
ROCKY TRANSITION (N=20)							
Bromus rubens	.85	10.750	10.223	22.800	22.719	0.359	0.542
Erodium cicutarium	.60	2.100	3.370	6.200	10.309	0.098	0.147
Schismus barbatus	.30	0.850	1.927	1.450	3.364	0.006	0.014
Bromus tectorum	.10	0.100	0.308	0.200	0.616	0.001	0.004
Lepidium flavum	.05	0.050	0.224	0.100	0.447	0.001	0.006
Pectocarya recurvata	.05	0.050	0.224	0.050	0.224	0.001	0.003
Plantago patagonica	.05	0.050	0.224	0.050	0.224	<.001	<.001
Unk forb	.10	0.250	0.910	0.400	1.569	0.005	0.019
ROCKY (N=20)							
Bromus rubens	.45	9.500	29.848	0.500	26.611	0.251	0.869
Erodium cicutarium	.20	5.950	25.440	9.700	40.821	0.139	0.596
Cryptantha virginensis	.10	0.150	0.489	0.450	1.395	0.003	0.013
Schismus barbatus	.10	0.350	1.348	0.750	3.127	0.002	0.011
Thysanocarpus curvipes	.10	0.150	0.489	0.550	1.877	0.003	0.009
Bromus tectorum	.05	1.000	4.472	2.450	10.957	0.039	0.173
Cryptantha angustifolia	.05	0.100	0.447	0.450	2.012	0.005	0.022
Descurainia pinnata	.05	0.100	0.447	0.150	0.671	<.001	0.001
Eriastrum eremicum	.05	0.050	0.224	0.100	0.447	0.001	0.005
Gilia sp	.05	0.050	0.224	0.200	0.894	0.001	0.006
Microseris lindleyi	.05	0.100	0.447	0.200	0.894	0.004	0.016
Plantago patagonica	.05	0.950	4.249	0.700	3.130	0.011	0.049
Silene antirhhina	.05	0.050	0.224	0.200	0.894	0.001	0.004

4.2.2 Littlefield

This is the first season we have collected data at Littlefield. However, comparable data are available in Hohman and Ohmart (1980). The flora of the Littlefield site included 56 species (Appendix II) and may be expected to increase during subsequent years of greater precipitation.

Line-intercept data revealed that 51.6% of the perennial flora were represented in vegetation transects. Mean cover of perennial species was greatest in Wash habitat while the least amount of mean cover occurred in *Larrea-Ambrosia* habitat.

We found 18 species on annual quadrats. Wash habitat was the most diverse with 13 species, while the other three habitat types each had 11 species. Of the total annual flora, 65.2% were encountered during annual quadrat sampling in 1990. *Bromus spp.*, *Erodium cicutarium* and *Schismus barbatus* were prevalent at Littlefield and constituted a large percentage of the available annual flora. Community coefficients for annual species between habitat types were all greater than 50% (Table 5). An account of the distribution of growth forms is summarized in Table 1.

Table 5: Community coefficients of annual vegetation in each of four habitat types at Littlefield study plot, Littlefield, Arizona in 1990.

	HABITAT TYPE		
	Larrea-Ambrosia (LA)	**Larrea-Ambrosia-Ceratoides (LAC)**	**Larrea-Ambrosia-Hilaria (LAH)**
Wash	75	92	67
LAH	73	64	X
LAC	82	X	X

Total mean biomass for the Littlefield site was 21.53 kg/ha. *Bromus spp.*, *Erodium cicutarium*, *Plantago sp.* and *Schismus barbatus* contributed the greatest to the biomass, cover and density of extant annual species (Table 6). The greatest biomass occurred in LAH and Wash habitats (45.7 kg/ha and 40.6

kg/ha, respectively) while LA and LAC had considerably less biomass production (26 kg/ha and 15.3 kg/ha, respectively).

We apparently missed a summer bloom at the Littlefield site due to summer rain in July; however, there had been considerable biomass available in August (Tim Duck *pers. comm.*). Annuals were not sampled at Littlefield in 1989.

Table 6. Descriptive statistics for annual vegetation among four habitat types at Littlefield, Arizona in 1990.

	Freq.	Mean Dens. (#/m^2)	Std. Dev.	Mean Cover (cm^2/m^2)	Std. Dev.	Mean Mass (g/m^2)	Std. Dev.
L-A (N=40)							
Schismus barbatus	.97	58.15	74.141	65.725	81.191	0.461	0.646
Bromus rubens	.95	37.375	58.593	41.575	63.306	0.682	1.060
Erodium cicutarium	.95	27.850	31.181	38.037	47.267	1.251	1.711
Plantago patagonica	.62	4.475	8.171	8.143	15.458	0.147	0.305
Eriogonum thomasii	.23	0.425	1.083	9.050	23.955	0.019	0.062
Lepidium flavum	.15	0.325	0.971	0.587	2.016	0.009	0.033
Chorizanthe brevicornu	.13	3.000	3.566	21.400	28.927	0.117	0.161
Lesquerella tenella	.13	0.225	0.733	1.413	8.053	0.009	0.042
Monoptilon bellioides	.10	0.077	0.270	0.051	0.192	0.002	0.009
Unident. Composite	.08	0.025	0.158	0.100	0.632	0.001	0.004
Lotus sp.	.03	0.025	0.158	0.100	0.632	<0.001	0.003
L-A-C (N=20)							
Schismus barbatus	.95	73.650	60.348	90.150	124.700	0.598	0.537
Plantago patagonica	.95	23.600	18.571	21.500	17.261	0.409	0.313
Bromus rubens	.65	16.800	34.628	35.600	91.661	0.390	0.903
Eriogonum thomasii	.45	1.950	5.083	44.050	114.200	0.078	0.186
Erodium cicutarium	.40	0.650	1.182	0.825	1.844	0.017	0.031
Lesquerella tenella	.30	0.600	2.010	1.700	4.703	0.020	0.052
Monoptilon bellioides	.25	0.650	2.007	0.325	0.730	0.004	0.011
Descurainia pinnata	.10	0.100	0.308	0.750	2.314	0.006	0.020
Chorizanthe brevicornu	.05	0.050	0.224	0.100	0.447	0.001	0.003
Pectocarya recurvata	.05	0.100	0.447	0.300	1.342	0.001	0.005
Lepidium flavum	.05	0.050	0.224	0.050	0.224	<0.001	<0.001
L-A-H (N= 25)							
Schismus barbatus	1.0	207.880	117.615	225.480	181.995	2.635	2.545
Plantago patagonica	1.0	16.720	10.601	21.000	13.086	0.356	0.233
Eriogonum thomasii	.92	4.880	4.490	157.480	238.390	0.532	0.724
Bromus rubens	.88	47.250	67.917	54.083	71.250	1.001	1.344
Erodium cicutarium	.52	0.320	4.497	4.620	8.250	0.165	0.248
Eriastrum eremicum	.28	0.640	1.150	1.740	4.719	0.019	0.042
Bromus tectorum	.20	1.040	3.360	2.320	7.052	0.023	0.076
Lepidium flavum	.08	0.200	0.645	0.200	0.722	0.003	0.009
Monoptilon bellioides	.04	1.160	2.764	0.760	1.838	0.015	0.044
Lotus sp.	.04	*	*	*	*	0.001	0.003
Unident. sp.	.04	0.040	0.200	0.120	0.600	0.001	0.004
WASH (N=40)							
Bromus rubens	.88	6.325	6.391	12.275	9.106	0.189	0.204
Schismus barbatus	.53	12.500	25.978	23.525	42.130	0.092	0.164
Erodium cicutarium	.48	2.000	3.320	5.475	9.131	0.108	0.204
Plantago patagonica	.18	0.157	0.385	0.600	1.676	0.004	0.013
Eriogonum thomasii	.10	0.100	0.304	0.700	2.233	0.001	0.004
Descurainia pinnata	.05	0.050	0.221	0.375	1.835	0.002	0.011
Euphorbia micromera	.05	0.050	0.221	0.075	0.350	<0.001	0.001
Lepidium flavum	.05	0.050	0.221	0.150	0.802	0.002	0.008
Bromus tectorum	.03	0.050	0.316	0.125	0.791	0.002	0.014
Chorizanthe brevicornu	.03	0.025	0.158	0.050	0.316	<0.001	0.002
Lesquerella tenella	.03	0.025	0.158	0.150	0.949	0.002	0.010
Pectocarya recurvata	.03	0.025	0.158	0.125	0.791	0.003	0.016
Monoptilon bellioides	.03	0.025	0.158	0.025	0.158	0.001	0.004

* sample not measured

4.3 Tortoise observations and Fecal analysis

4.3.1 City Creek

There were no mortalities recorded for radio-transmittered tortoises. Two adult tortoises and one juvenile were found dead. No tortoises were observed to have signs of Upper Respiratory Tract Disease Syndrome(URTDS) by researchers working under the permit for this project.

During feeding observations, tortoises at City Creek ate 46 food species during 267 hours of field observation in 1990. These items consisted of 26 annual forbs, 2 annual grasses, 12 perennial shrubs, 2 perennial grasses, and 4 additional food items such as rock, fecal pellets, unknown grass and unknown forb (Table 7). We recorded over 29,000 bites compared to last year's 11,654 bites. Of the total observation time, tortoises spent 23% (61 hours) feeding.

Fecal analysis was conducted on 59 fecal pellets collected at City Creek in three time periods in 1990 (14 collected from 8 April - 23 April, 21 from 3 May - 30 May, and 24 from 2 June - 25 June). Fecal analysis provided evidence of 41 food species in 1990. Of these food items were: 3 annual forbs, 2 annual grasses, 18 perennials, 5 perennial grasses and 13 minor additional food items including flower parts, unknown plants, parts of arthropod and rock (Table 7).

Tortoises ate bones presented to them during 8 of 11 bone-eating trials. As was previously observed (Esque *et al.* 1990), tortoises were persistent in osteophagous behavior, and they often ate bones even while being photographed (1-2 m distance). This persistent behavior was strikingly different than normal feeding observation behavior due to the fact that a wild desert tortoise feeding on plants was more likely interrupted by the presence of an observer.

4.3.2 Littlefield

General health of radio-transmittered tortoises also was good. No outward signs of URTDS were observed by researchers working on this research project.

Based on feeding observations, tortoises at Littlefield consumed 16 plant species during 187 hours of tortoise observation (4 annual forbs, 2 annual grasses, 4 perennial shrubs, 3 perennial grasses, and 3 additional food items

including rock, fecal pellet and unknown forbs (Table 8). Of the total observation time, tortoises spent 6.4% (12 hours) feeding. More than 7,000 bites were recorded in 1990.

Fecal analysis at Littlefield was performed on 25 fecal pellets in a three month period in 1990 (9 collected from 23 April - 27 April, 9 from 1 May - 25 May, and 7 from 5 June - 21 June). Fewer pellets were collected at Littlefield than at the City Creek site because there were fewer fecal pellets available. Fecal analysis provided evidence of 22 food species eaten at Littlefield in 1990 (3 annuals, 2 annual grasses, 8 perennials, 3 perennial grasses, and 6 additional food items including parts of plants, unidentified plants, parts of arthropods and rock) (Table 8).

Table 7: Food items present in feeding observations and fecal analysis at City Creek, Utah,1990.

SPECIES	# BITES TOTAL	%BITES	%FECAL
Bromus rubens	12069	38.56	31.45
Schismus barbatus	8114	25.92	7.72
Erodium cicutarium	2920	9.33	14.62
Cryptantha micrantha	1022	3.26	2.44
Bromus tectorum	1020	3.26	*
Oryzopsis hymenoides	744	2.38	6.24
Stephanomeria exigua	602	1.92	
Litter	534	0.71	
Gaura coccinea	506	1.62	
Streptanthella longirostris	375	1.20	
Aristida purpurea	339	1.08	4.93
Coleogyne ramosissima	312	1.00	
Eriophyllum wallacei	297	0.95	
Unknown forb	277	0.88	
Phacelia ivesiana	260	0.83	
Fecal pellet	248	0.79	
Abronia fragrans	245	0.78	
Cryptantha virginensis	238	0.76	*
Krameria parvifolia	155	0.50	*
Chorizanthe thurberi	131	0.42	
Gilia leptomeria	89	0.28	
Cryptantha angustifolia	87	0.28	*
Pectocarya recurvata	81	0.26	
Salsola iberica	57	0.18	
Descurainia pinnata	56	0.18	
Unknown grass	56	0.18	
Euphorbia parryi	52	0.17	
Echinocereus engelmannii	49	0.16	2.2
Eriastrum eremicum	47	0.15	
Cryptantha sp.	43	0.14	*
Rock	38	0.12	
Eriogonum fasciculatum	31	0.10	
Oenothera pallida	26	0.08	1.3
Cryptantha nevadensis	25	0.08	*
Helianthus anomalus	22	0.07	
Gutierrezia sp.	21	0.07	0.25
Opuntia sp.	21	0.07	*
Eriogonum inflatum	19	0.06	*
Ephedra nevadensis	17	0.05	
Plantago patagonica	17	0.05	0.61
Eriogonum maculatum	12	0.04	*
Thysanocarpus curvipes	9	0.03	
Heterotheca villosa	6	0.02	
Yucca utahensis	4	0.01	0.08
Dithyrea wislizenii	3	0.01	0.21
Eriogonum thomasi	3	0.01	*
Androstephium breviflorum	2	0.01	
Opuntia erinacea	1	<.01	*
TOTAL	31302	100.00	

*Most fecal pellets identified only to genus, so those species were combined

Table 8: Food items present in feeding observations and fecal analysis at Littlefield, Arizona,1990.

SPECIES	# BITES TOTAL	%BITES	%FECAL
Schismus barbatus	3133	44.33	24.12
Erodium cicutatrium	1484	21.00	21.85
Bromus rubens	828	11.71	3.15
Opuntia basilaris	567	8.02	1.26
Erioneuron pulchellum	311	4.40	
Plantago patagonica	224	3.17	26.21
Hilaria rigida	216	3.06	
Oryzopsis hymenoides	112	1.58	
Unknown	107	1.51	
Krameria sp.	23	0.33	
Mirabilis sp.	20	0.28	
Rock	17	0.24	
Eriogonum thomasii	8	0.11	0.08
Plantago insularis	7	0.10	*
Fecal pellets	7	0.10	
Ceratoides lanata	4	0.06	
TOTAL	7068	100.00	

*Most fecal pellets identified only to genus, so those species were combined.

4.4 Home Range

Home ranges were based on cumulative recaptures during the spring activity period beginning at the end of March, when tortoises were located for the first time, through 15 June when most of the tortoises quiescent. This time period was the same for the 1989 spring activity period; thus, the 1990 data are comparable to the 1989 data.

The estimate for home range size using minimum convex polygon method was about one-half the size of the non-circular plot method. Mean home range size was significantly larger (P = .0876) at the City Creek site in 1990 than in 1989 (means: 12.079 ha vs. 7.88 ha, N = 10 each) (Table 9). Mean home range size was also significantly larger (P = .0078, N = 10) at the City Creek site than at the Littlefield site in 1990 (means: 12.079 ha vs. 3.663 ha, N = 10). The actual home ranges for each tortoise are represented in Appendix III.

Table 9: Mean home range estimates (ha) for tortoises at the City Creek, Utah and Littlefield, Arizona study sites (Spring activity period, 1989 and 1990).

CITY CREEK			LITTLEFIELD	
Tortoise#	1989	1990	Tortoise#	1990
393	4.05	8.27	HO37	1.68
1244	0.33	4.06	209	0.22
1190	7.66	13.07	207	10.97
1282	6.65	13.14	250	3.43
1281	2.50	14.55	210	1.23
1232	11.85	13.10	770	2.93
1234	6.45	0.11	S131	1.28
1198	3.33	13.39	HO68	0.17
1208	7.22	12.40	HO84	1.28
1150	6.38	11.12	HO67	2.69

4.5 Diet selection

The null hypothesis that tortoises fed randomly with respect to species encountered was rejected in all habitats at the City Creek site and Littlefield site in spring 1990. This suggests that tortoises selected (either positively or negatively) at least one species of plant over what was available to them in each habitat type. Tortoises appeared to select exotic species as well as some native species. As noted earlier, tortoises were observed feeding on forty-three species of plants at the City Creek site in 1990.

4.6 Plant nutrition

We collected 23 species of plants for nutritional analysis at City Creek including four species not sampled in 1989. At Littlefield, 17 species were collected for analysis including two additional species not sampled in 1989.

4.7 Fiber-optics

Dissection of dead tortoises showed that vegetation formed a loose bolus in the stomach that was larger in diameter than the anterior sphincter of the stomach.

Thus, extraction of the bolus by the gavage methods provided poor results. Also, an acute bend in the esophagus just anterior to the stomach limited maneuverability of the gavage tube.

On 30 June and 1 July, 1990 we sampled the stomach contents from desert tortoises in the laboratory and then in the field. Food items were retrieved from the stomachs of twelve wild desert tortoise using fiber-optic equipment. Most of the animals had partially full stomachs, while three had empty stomachs (Table 10). Ten tortoises of all those sampled had a stomach pH of 4 while two tortoises exhibited a stomach pH of 3 or 3.5 to 4.

Wild tortoises that were monitored for a minimum of four months prior to endoscopy demonstrated no unusual changes in behavior. No mortalities resulted during fiber optic procedures.

Table 10. Stomach contents and stomach pH of captive and wild tortoises at City Creek, Utah 30 June 1990.

Tortoise#	pH	Stomach Capacity	Contents
1280	4	empty	no sample
1150	4	partially full	*Bromus* sp., heads, cured
1282	4	partially full	*Bromus* sp. heads, cured
1234	4	partially full	male flowers: *Ephedra* sp., *Bromus* sp.
1198	4	partially full	*Bromus* sp., head
1209	4	empty	no sample collected
1287	–	very little	no sample collected
1288	4	partially full	*Oryzopsis hymenoides*, culm & blade
1290	3.5 - 4.0	partially full	*Mammilaria* sp. fruit, *Bromus* sp. head
366	–	empty	no sample collected
1289	4	partially full	*Bromus* sp., head
1191	3	partially full	*Bromus* sp., cactus spine
Captive #1	4	empty	no sample
Captive #3	4	empty	no sample
Captive #4	–	empty	no sample

5.0 DISCUSSION

5.1 Weather and Climate

Mean winter rainfall (October through December) for St. George, Utah and Littlefield, Arizona were both below the 61 and 33 year means, respectively (NOAA 1990). In fact, precipitation for November and December at Littlefield were the lowest recorded values since 1956. St. George also had its lowest recorded monthly mean precipitation for April and December 1989 since 1928. "Critical rainfall" necessary for the normal germination of winter annuals occurs late September through early December (Beatley 1974); therefore, the 1990 field season had low biomass production for both Littlefield and City Creek. Based on our annual plant sampling, biomass production was low at both Littlefield and City Creek (Tables 3 and 6).

5.2 Vegetation

Diversity of plant species was greater at City Creek than at Littlefield in 1990 as City Creek had about twice as many species represented in the flora. The heterogeneous nature of City Creek likely accommodated a greater diversity of plant species. The proportion of perennials, winter annuals, and summer annuals was essentially the same between the two sites.

In 1990, the community coefficients for annual species between City Creek and Littlefield were less than 45%. In contrast, the community coefficients between habitat types at City Creek were mostly less than 50% and at Littlefield they were all greater than 50%. Any time diversity of species occurs as low as 8 or 9 species, we may expect misleading results for community coefficients because of small sample sizes. Also at low diversity, four introduced species (*Bromus rubens, B. tectorum, Erodium cicutarium* and *Schismus barbatus*), which have become ubiquitous in the Mojave desert are common and skew the data set toward higher similarity. When compared to the 1989 species list from City Creek, the 1990 list had more species of both perennials and annuals. The greater number of species was probably due, in part, to better sampling of uncommon microhabitats. On the other hand, many of the new species may have occurred due to environmental factors (e.g., timing of precipitation) influencing germination of different seed stocks (Beatley 1974).

Biomass production in the Mojave desert may range form zero to over 1000 kg/ha (Lathrop and Rowlands 1983). In 1990, biomass production of winter annual vegetation at City Creek and Littlefield sites was extremely low and reflected drought conditions. The greatest total biomass for three data sets (City Creek 1989, City Creek 1990 and Littlefield 1990) was only 21.53 kg/ha at Littlefield in 1990. This was more than twice as much as found at City Creek in either year (i.e., 1989 = 8.79 kg/ha and 1990=7.59 kg/ha). When compared by habitat types, the mean biomass of each habitat type at Littlefield was significantly greater than those at City Creek in 1990 (P=.0102, 95% C.I, df=3). When individual habitats were compared among sites, mean biomass at Littlefield was greater than at City Creek in all habitat types in 1990. The greater biomass at City Creek in 1989 compared to 1990 was probably due to the timing of and amount of precipitation at City Creek in 1989.

Similar to mean biomass production at City Creek and Littlefield, mean cover and frequency were significantly different between the two sites. A paired, two-tailed t-test indicated that mean cover and mean frequency both were significantly lower at City Creek when compared to Littlefield in 1990 (P=.0982 and P=.0982, 95% C.I., df=3, respectively).

5.3 Tortoise Diet

When comparing feeding observations to fecal analysis we found a more complete composite of tortoise diet. Many of the species noted in feeding observations were not present in the fecal analysis and vice versa. In fact, feeding observations showed more annual species (68%), while fecal analysis demonstrated more perennials (74%). There were several peculiar occurrences of some species present in fecal pellets at both sites. Possibly, tortoises located and ingested some plants of the species which we did not detect during bite-count observations.

Comparison of feeding observations to fecal analyses yielded several interesting results. At Littlefield *Schismus* sp., *Erodium* sp. and *Bromus* sp. were highly utilized food items in both the bite-counts and in the fecal analysis, but the bite counts did not account for the large relative frequency of *Plantago* sp. as the fecal analysis demonstrated (bite counts-3.17%, fecal analysis-26.21%). For those plants at City Creek, the highly utilized species consumed

by tortoises were also represented in the bite-count observations--*Bromus* sp., *Erodium* sp. and *Schismus* sp.

Feeding observations and fecal analyses whad similar results when the most commonly occurring species were considered, however, consideration of the remaining species indicated that feeding observations had a preponderance of winter annual species. In contrast, fecal analysis has a higher percentage of perennial species represented. The fecal results for Littlefield are consistent with data accumulated by Hansen *et al.* (1976) and Hohman and Ohmart (1980), i.e., more perennial species were present in the diet.

The number of fecal pellets (N = 25) collected at Littlefield may have been inadequate for the analysis of tortoise diet; 15 or 20 fecal pellets are sufficient for an area to record at least 95% of the foods found in the diet (Anthony and Smith 1974). Most City Creek samples follow this specification, but Littlefield samples are wanting since they were more difficult to collect in 1990. This factor may account for the low similarity in the Littlefield samples. Continued bite count analysis and fecal analysis in the future will tell us more about tortoise diet and diet selection.

5.4 Home Range

The results indicate that tortoise home range size is dynamic over time. Further investigation is needed to better indicate the pattern of home ranges and how they shift according with varying environmental parameters.

Mortality data indicate that there was little change in the density of tortoises between 1989 and 1990 at City Creek. Therefore, we have no evidence that home ranges were density dependent. More likely, home ranges are more dependent on food quantity and perhaps food quality than tortoise density. But more data need to be collected, particularly in a year of greater biomass production. Alternatively, home ranges could center around hibernaculum, egg-laying sites or “social centers”.

5.5 Foraging selectivity

This analysis of diet choice in tortoises indicates that at least some plants are not chosen at random with regard to their occurrence in the habitat. Some plants that were so rare that they did not to occur in the vegetation analysis, resulting in zero frequencies. However, some of these species were heavily used by tortoises on the rare occasions when they were located. This inconsistency leaves a gap in the analysis where these potentially important species are not compared adequately with more abundant species. There was a difference in numbers recorded as food species by tortoises (N = 43) versus the number of species used in the selection analysis (N = 25). This discrepancy exists because only 25 species of plants were encountered on random vegetation transects. Therefore, tortoises were better at finding uncommon plant species than we were on random transects. The only way to counteract this discrepancy would be to sample vegetation more thoroughly and on a larger scale. This would be achieved by either sampling a larger number of quadrats or increasing the size of quadrats in order to capture those rare species. However, in order to acquire a statistically adequate sample of the rare species, we would elevate the frequencies of the most common species. The effect of that would be less differentiation of the selection of the common species. For example, if the five most common species occurred in above 90% of the quadrats, it would be difficult to distinguish the effect of tortoises feeding on one more frequently than the other. So we are left with a trade-off with existing technique. If it is determined that the rare species are more important to such an analysis, then we might consider varying techniques to account for the rare plants. An alternative to the trade-off would be to use two techniques for sampling the frequency of vegetation species. Assessing frequency of species is relatively less work intensive than assessing dry matter biomass for each species. Possibly frequency of plants could be collected at two scales and incorporating the relative frequencies of both common and rare species. The most important question with regard to that is, “would the resulting data sets be comparable?”

5.6 Fiber optics

Important insights were gained by our first field trial of fiberoptic techniques. We learned that it is important to sample the animals as soon as they are collected.

Otherwise, the food bolus may be passed out of the stomach. We do not know about the passage rates of the food bolus from the stomach. Because our sampling occurred late in the tortoises activity period (sampled 30 June and 1 July) tortoise stomachs likely were not as full as earlier in the spring.

The presence of cured *Bromus* sp. and *Oryzopsis hymenoides* in tortoise diets in summer reflects available forage at this time. The stomach fluid of the desert tortoise at City Creek had a slightly acidic pH. Comparable pH values throughout the season are needed to provide additional data on the changes of pH in relation to food items eaten.

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8.0 APPENDICES

Appendix I. Complete species list of vegetation at City Creek, Utah, 1990.

Perennials	**CODE**	**COMMON NAME**	**FAMILY**
Abronia fragrans	ABFR	Fragrant sand verbena	Nyctaginaceae
Allionia incarnata	ALIN		Nyctaginaceae
Ambrosia dumosa	AMDU	Bur-sage	Compositae
Androstephium breviflora	ANBR	Hyacinth	Liliaceae
Anemone tuberosa	ANTU	Desert Anemone	Ranunculaceae
Arenaria macradenia	ARMA	Shrubby Sandwort	Caryophyllaceae
Artemesia filifolia	ARFI	Sand Sagebrush; Old-man Sagebrush	Compositae
Atriplex canescens	ATCA	Four-wing Saltbrush	Chenopodiaceae
Baccharis sp.	Bacc.		Compositae
Calochortus nuttallii	CANU	Sego Lily	Liliaceae
Carex geyeri	CAGE	Elk Sedge	Cyperaceae
Castillega linariaefolia	CALI	Narrowleaf Paintbrush	Scrophulariaceae
Celtis reticulata	CERI	Netleaf Hackberry	Ulmaceae
Ceratoides lanata	CELA	Winterfat; White-sage	Chenopodiaceae
Chilopsis linearis	CHLI	Desert Willow	Bignoniaceae
Coleogyne ramossisima	CORA	Blackbrush	Rosaceae
Cowania mexicana	COME	Cliff-rose	Rosaceae
Croton californicus	CRCA	Mohave Croton	Euphorbiaceae
Delphinium nuttallianum	DENU	Nelson Larkspur	Ranunculaceae
Dichelostemma pulchellum	DIPU	Blue Dick	Liliaceae
Echinocereus engelmani	ECEN	Engelmann Hedgehog Cactus	Cactaceae
Encelia frutescens	ENFR	Bush Encelia	Compositae
Ephedra nevadensis	EPNE	Nevada Ephedra	Ephedraceae
Ephedra viridis	EPVI	Green Ephedra; Mormon Tea	Ephedraceae
Erigeron divergens	ERDI	Spreading Daisy	Compositae
Eriogonum fasciculatum	ERFA	Mojave Buckwheat	Polygonaceae
Eriogonum inflatum	ERIN	Bottlebush; Desert Trumpet	Polygonaceae
Fallugia paradoxa	FAPA	Apache Plume	Rosaceae
Fraxinus anomala	FRAN	Singleleaf Ash	Oleaceae
Gaura coccinia	GACO	Scarlet Gaura	Onagraceae
Gutierrezia microcephala	GUMI	Thread Snakeweed	Compositae
Gutierrezia sarothrae	GUSA	Broom Snakeweed	Compositae
Heterotheca villosa	HEVI	Hairy Goldenaster	Compositae
Hymenoclea salsola	HYSA	Burrobush	Compositae
Hymenopappus filifolius	HYFI	Hyalineherb	Compositae
Juniperus osteosperma	JUOS	Utah Juniper	Cupressaceae
Krameria parvifolia	KRPA	Range Ratany	Krameriaceae
Larrea tridentata	LATR	Creosote bush	Zygophyllaceae
Lepidium fremontii	LEFR	Desert allysum	Cruciferae
Lomatium scabrum	LOSC	Rough Lomatium; Cliff Lomatium	Apiaceae
Lotus rigidus	LORI	Bush trefoil	Leguminosae
Lycium sp.	Lycium		Solanaceae
Mammillaria tetrancistra	MATE	Corkseed cactus	Cactaceae
Nicotiana trigonophylla	NITR	Desert Tobacco	Solanaceae
Oenothera pallida	OEPA	Pale Evening-primrose	Onagraceae
Opuntia acanthocarpa	OPAC	Buckhorn Cholla	Cactaceae
Opuntia erinacea	OPER	Prickley Pear	Cactaceae
Pediomelum mephiticum	PEME	Skunk Breadroot	Leguminosae
Penstemon ambiguus	PEAM	Bush Penstemon; Gilia Penstemon	Scrophulariaceae
Penstemon eatoni	PEEA	Eaton Penstemon; Scarlet-bugler	Scrophulariaceae
Prosopis pubescens	PRPU	Screwbean Mesquite	Leguminosae
Notholaena sp.	Nothol.	Cloak-fern	Polypodiaceae
Prunus fasciculata	PRFA	Desert Peach	Rosaceae
Rhus trilobata	RHTR	Skunkbush	Anacardiaceae
Rumex hymenosepalus	RUHY	Canaigre	Polygonaceae
Salazaria mexicana	SAME	Bladdersage; Paperbag Bush	Labiatae
Selaginella watsonii	SEWA	Watson Spikemoss	Selaginellaceae

Appendix I (cont).

Perennials	**CODE**	**COMMON NAME**	**FAMILY**
Senecio douglasii	SEDO	Douglas Groundsel	Compositae
Sphaeralcea ambigua	SPAM	Desert mallow	Malvaceae
Stephenomeria paucifolia	STPA	Fewflower Wirelettuce	Compositae
Tamarix pentandra	TAPE	Tamarisk; Saltcedar	Tamaricaceae
Tetradymia spinosa	TESP	Thorny Horsebush	Compositae
Yucca baccata	YUBA	Datil yucca; Fleshy-fruited yucca	Agavaceae
Yucca utahensis	YUUT	Utah yucca	Agavaceae
Perennial grasses			
Aristida purpurea	ARPU	Purple Threeawn	Graminae
Elymus elymoides	ELEL	Squirreltail	Graminae
Erioneuron pulchellum	ERPU	Fluffgrass	Graminae
Hilaria rigida	HIRI	Big Galleta	Graminae
Muhlenbergia porteri	MUPO	Bush Muhly	Graminae
Oryzopsis hymenoides	ORHY	Indian Ricegrass	Graminae
Sporobolus flexuosus	SPFL	Mesa Dropseed	Graminae
Stipa speciosa	STSP	Desert Needlegrass	Graminae
Tridens muticus	TRMU	Slim Tridens	Graminae
Winter annuals			
Amsinkia tessellata	AMTE	Rough Fiddleneck	Boraginaceae
Bromus rubens	BRRU	Red Brome; Foxtail Brome	Graminae
Bromus tectorum	BRTE	Cheatgrass; downy Chess	Graminae
Camissonia andina	CAAN		Onagraceae
Chenopodium album	CEAL	Lambsquarter; Pigweed	Chenopodiaceae
Chorizanthe brevicornu	CHBR	Short spine-flower	Polygonaceae
Chorizanthe rigida	CHRI	Rigid Spine-flower	Polygonaceae
Chorizanthe thurberi	CHTH	Thurber Spine-flower	Polygonaceae
Corydalis aurea	COAU	Golden Corydalis	Fumariaceae
Cryptantha angustifolia	CRAN	Narrowleaf Cryptanth	Boraginaceae
Cryptantha micrantha	CRMI	Dye Cryptanth	Boraginaceae
Cryptantha nevadensis	CRNE	Nevada Cryptanth	Boraginaceae
Cryptantha virginensis	CRVI	Virgin Cryptanth	Boraginaceae
Datura meteloides	DAME	Sacred Datura	Solanaceae
Descurainia pinnata	DEPI	Pinnate Tansy-mustard	Cruciferae
Dithyrea wislizenii	DIWI	Spectacle-pod	Cruciferae
Draba cuneifolia	DRCU	Wedgeleaf	Cruciferae
Eriastrum eremicum	ERER	Desert gilia	Polemoniaceae
Eriogonum maculatum	ERMA	Red-spotted Buckwheat	Polygonaceae
Eriogonum thomasii	ERTH	Thomas Buckwheat	Polygonaceae
Eriophyllum wallacei	ERWA	Wallace Woollyleaf; Woolly Daisy	Compositae
Erodium cicutarium	ERCI	Storksbill	Geraniaceae
Eschscholtzia minutiflora	ESMI	Little gold-poppy	Papaveraceae
Euphorbia parryi	EUPA	Parry Spurge	Euphorbiaceae
Gilia leptomeria	GILE		Polemoniaceae
Gilla sp.	GILIA		Polemoniaceae
Helianthus anomalus	HEAN	Sand Sunflower	Compositae
Lepidium flavum	LEFL	Yellow pepper-grass	Cruciferae
Lesquerella tenella	LETE	Slender Bladderpod	Cruciferae
Lupinus concinnus	LUCO	Elegant Lupine	Leguminosae
Mentzelia albicaulis	MEAL	Small-flowered blazing star	Loasaceae
Microseris lindleyi	MILI	Silver-puffs	Compositae
Oenothera brevipes	OEBR	Yellow cups	Onagraceae
Palafoxia arida	PAAR	Spanish Needle	Compositae
Pectocarya recurvata	PERE	Bent Combseed	Boraginaceae
Pectocarya setosa	PESE	Saucer Combseed	Boraginaceae
Phacelia ambigua	PHAM	Notch-leaf phacelia	Hydrophyllaceae
Phacelia ivesiana	PHIV	Ives phacelia	Hydrophyllaceae
Phacelia tanacetifolia	PHTA	Lacy phacelia	Hydrophyllaceae
Plagiobothrys arizonicus	PLAR	Stainplant	Boraginaceae
Plantago patagonica	PLPA		Plantaginaceae

Appendix I (cont.)

Winter annuals	**CODE**	**COMMON NAME**	**FAMILY**
Salsola iberica	SAIB	Russian-thistle; Tumbleweed	Chenopodiaceae
Schismus barbatus	SCBA	Mediterranean Grass	Graminae
Silene antirrhina	SIAN	Catch-fly	Caryophyllaceae
Stephanomeria exigua	STEX	Annual Wirelettuce	Compositae
Streptanthella longirostris	STLO	Long-beaked twist-flower	Compositae
Thysanocarpus curvipes	THCU	Fringe-pod	Cruciferae
Summer annuals			
Bouteloua aristidoides	BOAR	Needle Grama	Graminae
Pectis papposa	PEPA	Chinch-weed	Compositae
Biennial or Perennial			
Arabis drummondii	ARDR	Rockcress	Cruciferae
Baileya multiradiata	BAMU	Desert Marigold	Compositae
Baileya pleniradiata	BAPL		Compositae

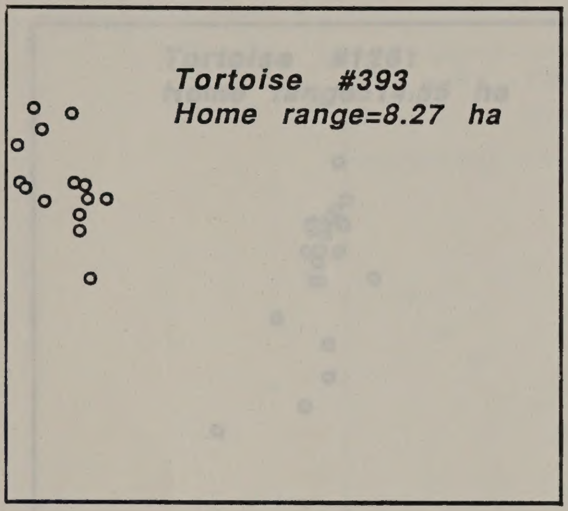
Appendix II. Complete species list of vegetation at Littlefield, Arizona, 1990.

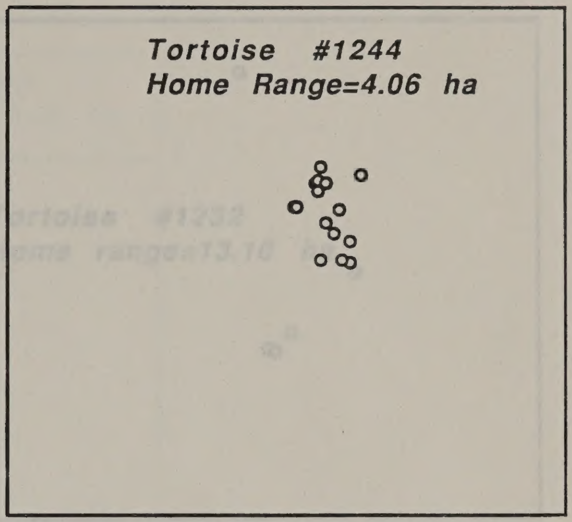
Perennials	**CODE**	**COMMON NAME**	**FAMILY**
Ambrosia dumosa	AMDU	Bur-sage	Compositae
Androstephium breviflorum	ANBR	Hyacinth	Liliaceae
Atriplex canescens	ATCA	Four-wing saltbrush	Chenopodiaceae
Baccharis sp.	Bacc.	Baccharis	Compositae
Ceratoides lanata	CELA	Winterfat; White-sage	Chenopodiaceae
Cynanchum utahense	CYUT	Swallow-wort	Astragulaceae
Dyssodia pentachaeta	DYPE	Scale Glandweed	Compositae
Echinocereus engelmani	ECEN	Engelmann Hedgehog-cactus	Cactaceae
Ephedra nevadensis	EPNE	Nevada ephedra	Ephedraceae
Eriogonum inflatum	ERIN	Bottlebush; Desert Trumpet	Polygonaceae
Ferocactus acanthodes	FEAC	Barrel Cactus	Cactaceae
Hymenoclea salsola	HYSA	Burrobush	Compositae
Krameria greyi	KRGR	White Ratany	Krameriaceae
Krameria parvifolia	KRPA	Range Ratany	Krameriaceae
Larrea tridentata	LATR	Creosote bush	Zygophyllaceae
Lycium andersonii	LYAN	Anderson Wolfberry	Solanaceae
Lycium sp.	Lyc.		Solanaceae
Opuntia basilaris	OPBA	Beaver-tail Cactus	Cactaceae
Opuntia erinacea	OPER	Prickley Pear	Cactaceae
Senecio douglasii	SEDO	Douglas Groundsel	Compositae
Sphaeralcea ambigua	SPAM	Desert mallow	Malvaceae
Stephenomeria sp.	STPA	Fewflower Wireletucce	Compositae
Tetradymia spinosa	TESP	Thorny Horsebush	Compositae
Tiquilia canescens	TICA	Hairy Tiquilia	Boraginaceae
Psoralea castorea	Psor.	Beaver Dam Breadroot	Leguminasae
Perennial grasses			
Aristida purpurea	ARPU	Purple threeawn	Graminae
Erioneuron pulchellum	ERPU	Fluffgrass	Graminae
Hilaria rigida	HIRI	Big Galleta	Graminae
Muhlenbergia porteri	MUPO	Bush Muhly	Graminae
Oryzopsis hymenoides	ORHY	Indian Ricegrass	Graminae
Tridens muticus	TRMU	Slim Tridens	Graminae
Winter annuals			
Bromus rubens	BRRU	Red brome;Foxtail brome	Graminae
Bromus tectorum	BRTE	Cheatgrass; Downy chess	Graminae
Chaenactis fremontii	CHFR	Fremont Dusty-maiden	Compositae
Chorizanthe brevicornu	CHBR	Short spine-flower	Polygonaceae
Chorizanthe rigida	CHRI	Rigid Spine-flower	Polygonaceae
Datura meteloides	DAME	Sacred Datura	Solanaceae
Descurainia pinnata	DEPI	Pinnate Tansy-mustard	Cruciferae
Eriastrum eremicum	ERER		Polemoniaceae
Eriogonum thomasii	ERTH	Thomas Buckwheat	Polygonaceae
Erodium cicutarium	ERCI	Storksbill; Red filaree	Geraniaceae
Eschscholtzia minutifolia	ESMI		Papaveraceae
Euphorbia micromera	EUMI		Euphorbiaceae
Gilia sp.	Gilia		Polemoniaceae
Langloisia schottii	LASC		Polemoniaceae
Lepidium flavum	LEFL		Cruciferae
Lesquerella tenella	LETE	Slender Bladderpod	Cruciferae
Lotus sp.	Lotus		Leguminosae
Monoptilon bellioides	MOBE		Compositae
Oenothera brevipes	OEBR		Onagraceae
Pectocarya recurvata	PERE	Bent Combseed	Boraginaceae
Plantago patagonica	PLPA		Plantaginaceae
Rafnesquia neomexicana	RANE	Desert Chicory	Compositae
Schismus barbatus	SCBA	Mediterranean Grass	Graminae

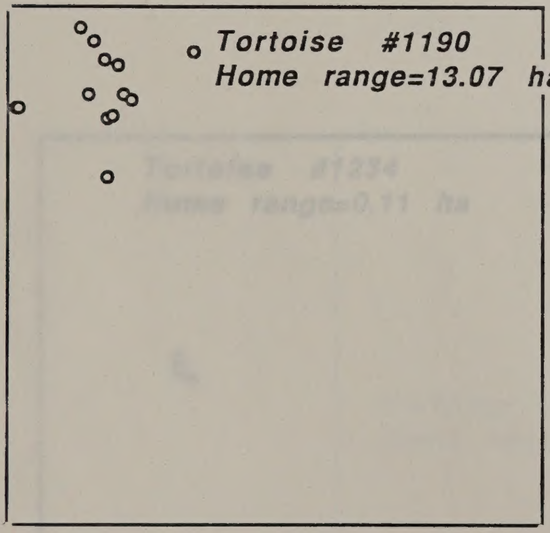
Appendix II (Cont.)	CODE	COMMON NAME	FAMILY
Summer annuals			
Pectis papposa	PEPA	Chinch-weed	Compositae
Biennial or perennial			
Baileya pleniradiata	BAPL		Compositae
Baileya multiradiata	BAMU	Desert marigold	Compositae

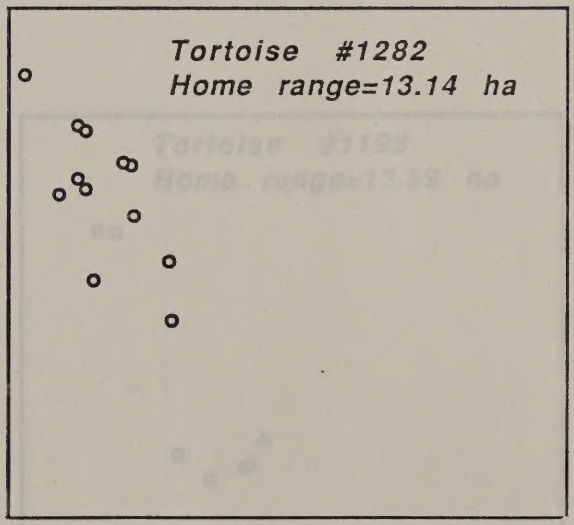
Appendix III. Tortoise home ranges for City Creek, Utah and Littlefield, Arizona.

City Creek

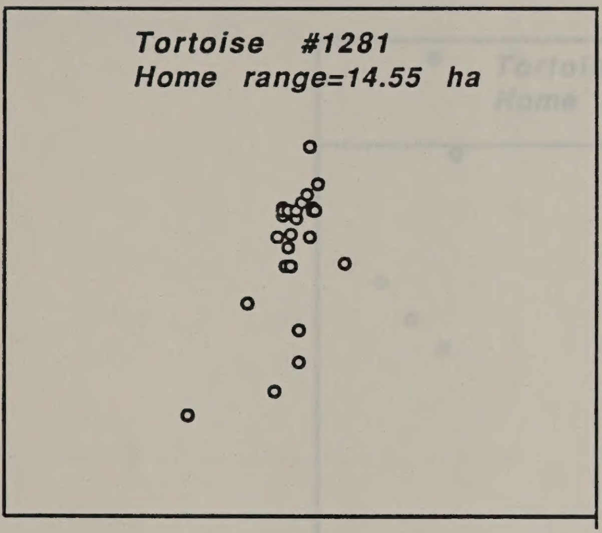


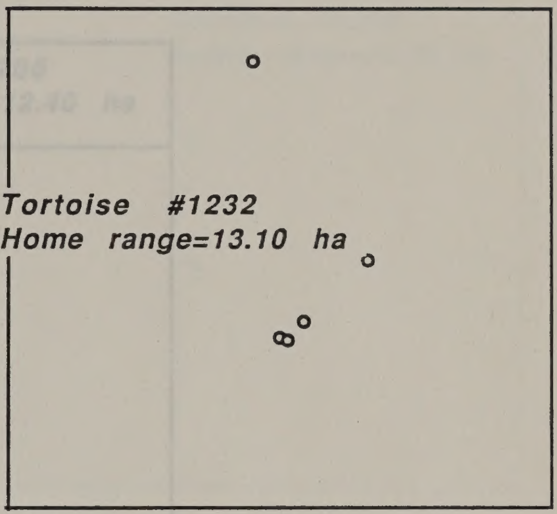


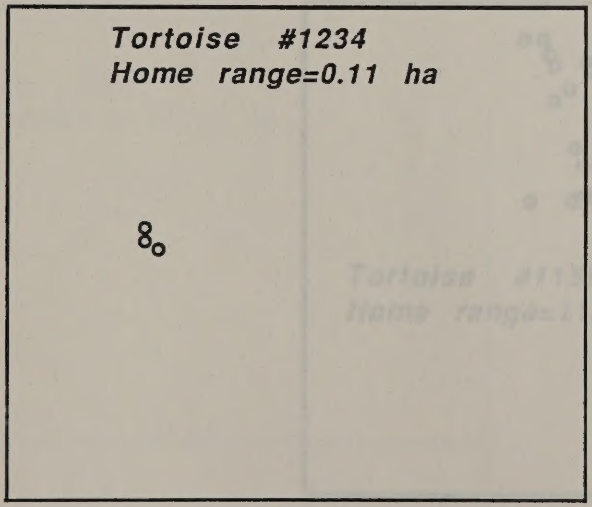


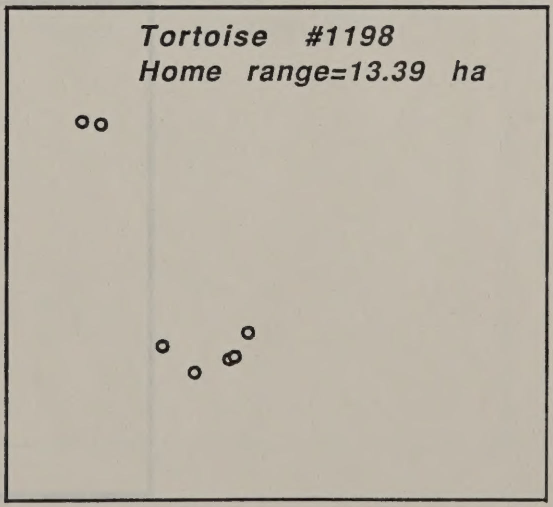


Appendix III (Cont.). City Creek Tortoise Home Ranges.

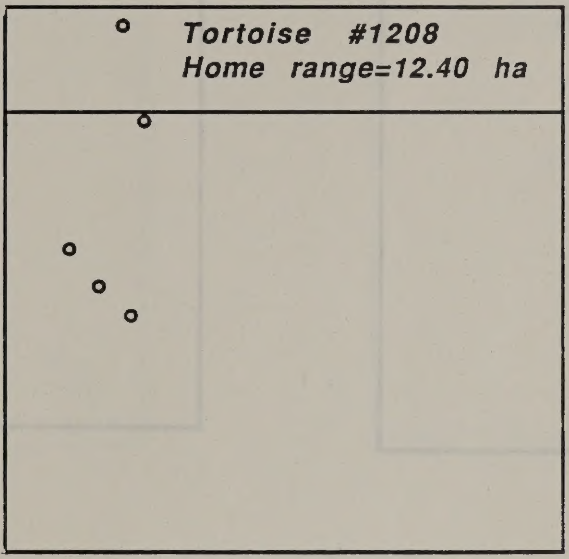


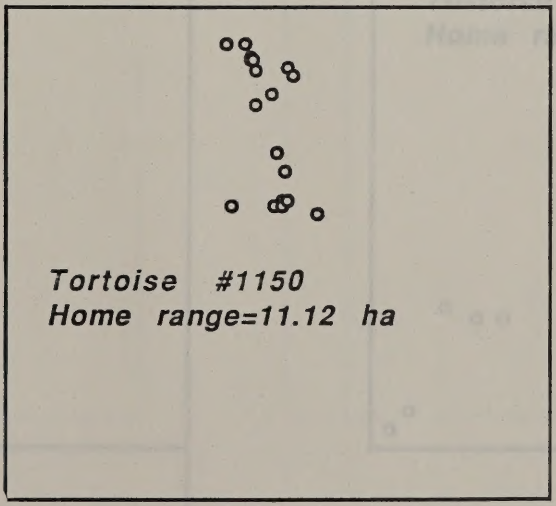




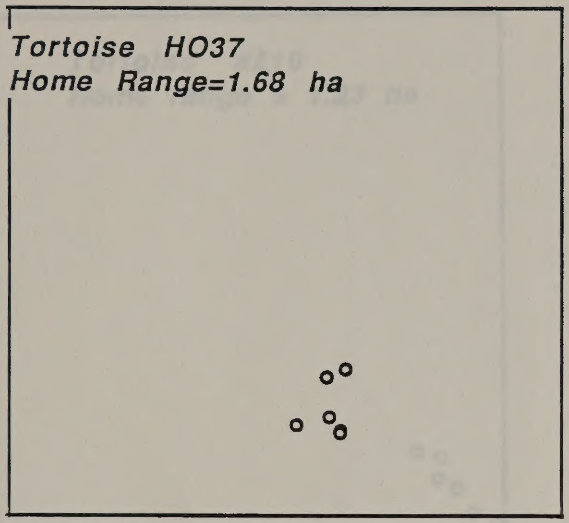


Appendix III (Cont.). City Creek Tortoise Home Ranges.

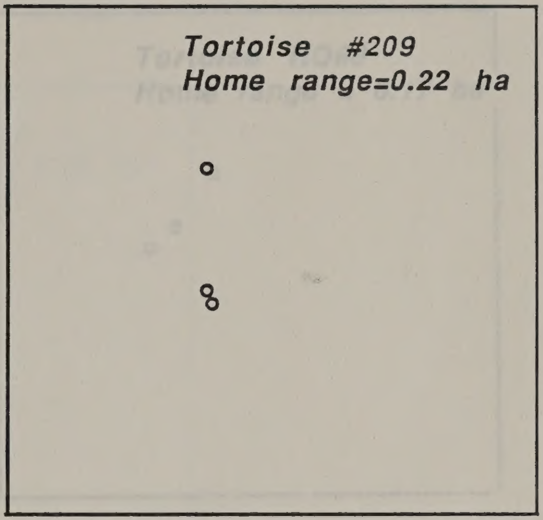




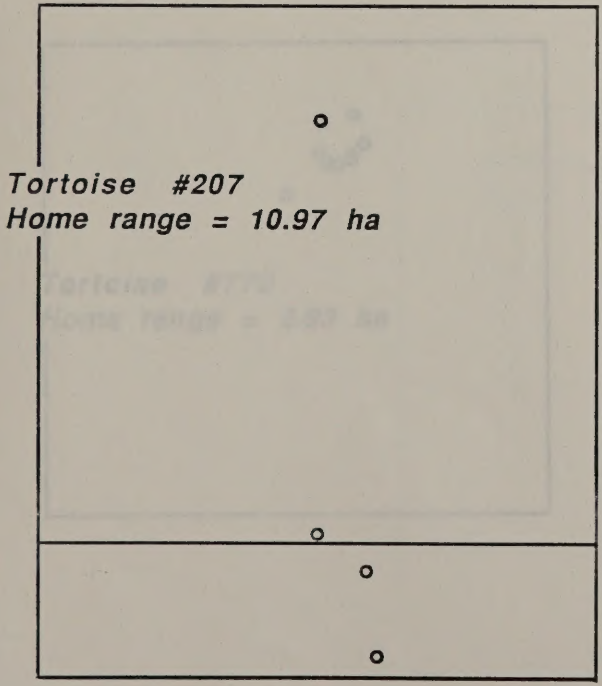
Appendix III (Cont.). Littlefield, Arizona Tortoise Home Ranges.



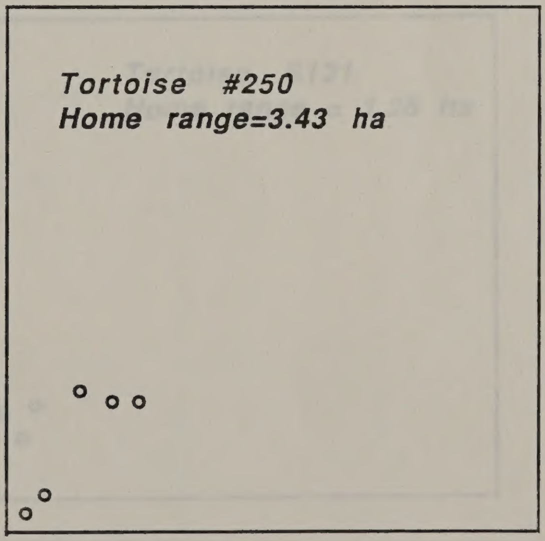
Tortoise HO37
Home Range=1.68 ha



Tortoise #209
Home range=0.22 ha

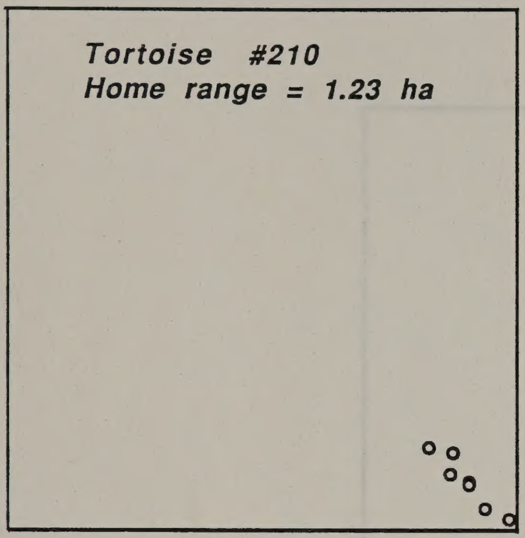


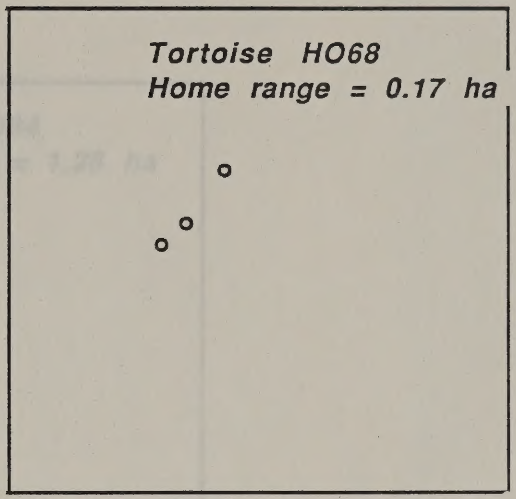
Tortoise #207
Home range = 10.97 ha

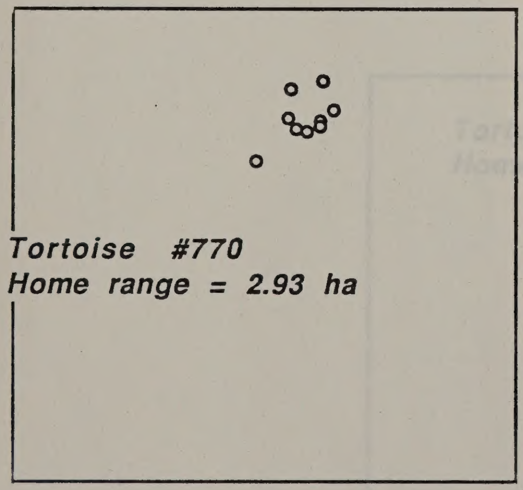


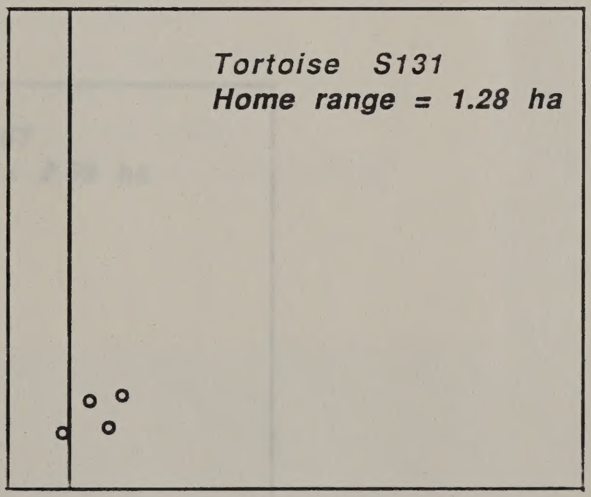
Tortoise #250
Home range=3.43 ha

Appendix III (Cont.). Littlefield, Arizona Tortoise Home Ranges.

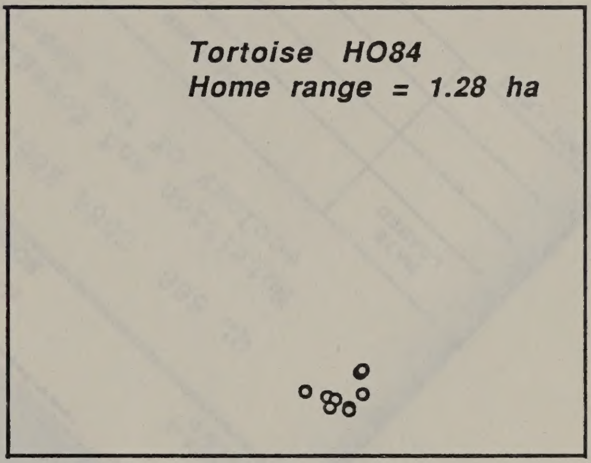


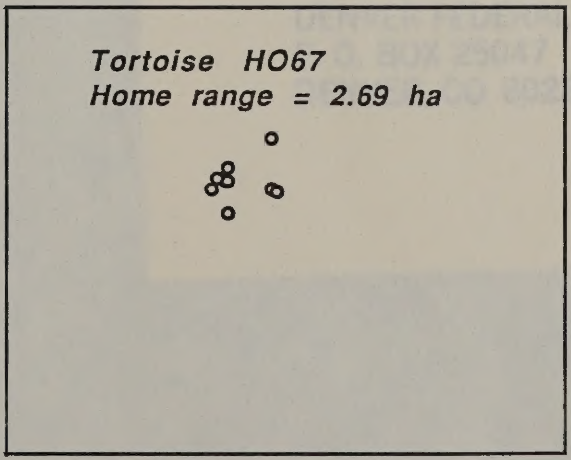






Appendix III (Cont.). Littlefield, Arizona Tortoise Home Ranges.





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